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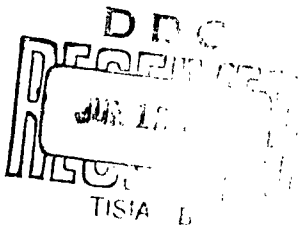
Report No. 8926-163

Material - Aluminum - 7178-T6

Effect of Interrupted Aging Treatments on Mechanical Properties

P. W. Bergstedt., H. C. Turner, W. M. Sutherland

29 January 1957



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Material - Aluminum - 7178-T6

Effect of Interrupted Aging Treatments on Mechanical Properties

Abstract:

Bare 0.064" thick 7178-0 sheet, clad 0.064" thick 7178-T6 sheet, and 0.125" thick 1-1/4" by 1-1/4" extruded 7178-0 angle was solution heat treated at 870°F for 30 minutes (0.064" thick), or 40 minutes (0.125" thick), quenched in cold water and aged with a variety of interrupted aging treatments which consisted of two steps; an initial nucleation treatment and a final growth treatment. The nucleation treatments used were 212°F for 4 hours and 230°F for 3 hours . The growth treatments used with the nucleation treatments included 325°F for 1, 2, 3, 4 and 5 hours. Most of the aging treatments produced excellent yield strengths, but ultimate strength and elongation losses were experienced in varying degree, although in all cases military specification minima were exceeded. The aging treatment consisting of 250°F for 3 hours plus 300°F for 4 hours produced the best and most consistent mechanical properties among those observed.

Reference: Bergstedt, P. W., Turner, H. C., Sutherland, W. M., "X7178-T6 Materials - Interrupted Aging Treatments," General Dynamics/Convair Report MP 56-239, San Diego, California, 29 January 1957. (Reference attached).

CONVAIR

A DIVISION OF GENERAL DYNAMICS CORPORATION

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ENGINEERING TEST LABORATORIES

REPORT 56-239

DATE 1-29-57

MODEL F-106

TITLE

REPORT NO. 56-239

X7178-T6 MATERIALS -

INTERRUPTED ARTIFICIAL AGING

TREATMENTS

MODEL F-106

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REFERENCE WADC Tech. Report 54-119
Lab. Record Book No. 910

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REPORT NO. 56-239
X7178-T6 MATERIALS-
INTERRUPTED ARTIFICIAL AGING
TREATMENTS

OBJECT:

1. To determine the tensile properties of X7178 aluminum alloy materials subjected to various interrupted-aging cycles after standard solution heat treatment.

2. To select a short term aging treatment which most nearly duplicates the mechanical properties obtained by standard aging practice.

CONCLUSIONS:

1. The minimum requirements of the respective military specifications were surpassed in all cases involving bare and extruded X7178 materials. The poor results obtained from the clad sheet cannot be attributed to short-time-aging effects. Most of the interrupted-aging treatments produced excellent yield strengths, but losses of varying degree were suffered in ultimate strength and ductility.

2. The best and most consistent results were obtained from the materials which were aged for 3 hours @ 250°F. plus 4 hours@ 300°F. The WADC recommendation of a 4 hour-4 hour treatment at these temperatures is in accord with these findings. The additional hour at the lower temperature does not appear to cause any significant changes in the tensile properties.

TEST PROCEDURE:

Three forms of X7178 aluminum alloy were involved in the interrupted-aging investigation:

1. Bare 0.064" X7178-O sheet
2. Clad 0.064" X7178-T6 sheet
3. 0.125" X7178-O Extruded 1 1/4" x 1 1/4" angle

Standard tensile specimens, prepared in accordance with QQ-M-151, were used throughout the test. Only longitudinal samplings were made, and the specimens were machined in the as-received conditions noted above.

Solution heat treatment was effected according to standard practice - 30 minutes at 870°F. for the 0.064" materials, and 40 minutes at 870°F. for the samples from the 0.125" extrusion.

After a water quench at room temperature, duplicate specimens were subjected to the various artificial aging treatments which appear in Tables I, II, and III.

TEST PROCEDURE: (Cont'd.)

The first tests were run on the bare sheet samples. After examination of the tensile test results from these specimens, the 1-hour treatment at the second aging temperature was dropped. Otherwise, the clad and extruded materials were aged according to the same schedule which was used for the bare sheet.

Laboratory circulating-air furnaces were used for both solution treatment and artificial aging. The tensile tests were performed on the 12,000 lb. Tinius-Olsen Testing Machine and in accordance with Federal Specification QQ-M-151. The tensile yield strength was taken at 0.2% offset, and the elongation was measured from a standard two-inch gauge section.

Before the test work had been completed, WADC Technical Report 54-119 was received at Convair. Since the interrupted-aging treatment considered best by WADC was not included in our work, additional specimens were prepared and heat treated per the WADC recommendation. These samples are noted in the tabulated data.

TEST RESULTS:

The tensile properties resulting from the various aging treatments of bare, clad, and extruded X7178 alloy are listed in Tables I, II, and III, respectively. Since the clad material was uniformly marginal with regard to specification minimums, no attempt was made to determine the cause of the low results. The significance of the various step-aging methods was ascertained by a comparison of results, short-time aging vs. standard aging. This was true of all the materials even though the bare and extruded X7178 yielded above-specification results in every instance.

To allow a rapid appraisal of the test data, Figure 1 was inserted in the report. Average values were used in all cases.

NOTE: The data from which this report was prepared are recorded in Laboratory Record Book No. 910.

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FORM 73

TABLE I.

EFFECT OF VARIOUS INTERRUPTED-AGING TREATMENTS ON THE MECHANICAL PROPERTIES OF 0.064" BARE X7178 SHEET.

Sample No.	Interrupted Aging Treatment		Mechanical Properties T.Y.S.	U.T.S.	% Elong.
3	212°F — 4 hrs.	Plus 1 hr @ 325°F	74,100	85,700	12.5
4			75,200	85,600	13.5
Avg.			74,650	85,650	13.0
5		Plus 2 hrs @ 325°F	80,400	85,900	10.5
6			79,600	86,400	10.0
Avg.			80,000	86,150	10.3
7		Plus 3 hrs @ 325°F	79,300	85,500	11.0
8			79,300	85,500	10.0
Avg.			79,300	85,500	10.5
9		Plus 4 hrs @ 325°F	80,900	86,000	11.0
10			79,700	85,800	11.0
Avg.			80,300	85,900	11.0
11		Plus 5 hrs @ 325°F	78,900	85,800	10.5
12			79,100	85,300	11.0
Avg.			79,000	85,550	10.8
13	310°F — 4 hrs.	Plus 1 hr @ 325°F	77,200	85,200	13.0
14			75,700	85,600	13.5
Avg.			76,450	85,400	13.3
15		Plus 2 hrs @ 325°F	78,200	86,300	13.5
16			78,100	85,800	12.0
Avg.			78,150	86,150	12.8
17		Plus 3 hrs @ 325°F	79,400	86,300	11.5
18			76,900	86,100	10.0
Avg.			78,150	86,200	10.7
19		Plus 4 hrs @ 325°F	79,700	86,100	10.0
20			80,700	86,300	11.0
Avg.			80,200	86,200	10.5
21		Plus 5 hrs @ 325°F	80,700	85,700	10.5
22			77,200	86,000	10.0
Avg.			78,950	85,850	10.3

Sample No	Interrupted Aging Treatment		Mechanical Properties T.Y.S.	U.T.S.	% Elong.
23	250°F — 3 hrs. @ 250°F	Plus 1 hr @ 300°F	77,400	86,900	13.0
24			78,700	88,000	12.5
Avg.			78,050	87,450	12.8
25		Plus 2 hrs @ 300°F	76,500	88,100	11.0
26			77,200	86,600	12.0
Avg.			77,850	87,350	11.5
27		Plus 3 hrs @ 300°F	80,000	86,800	11.5
28			79,400	86,600	12.0
Avg.			79,700	86,700	11.8
29		Plus 4 hrs @ 300°F	80,600	88,000	12.0
30			80,500	87,300	12.0
Avg.			80,550	87,650	12.0
31		Plus 5 hrs @ 300°F	80,700	87,300	10.5
32			81,100	87,500	10.5
Avg.			80,900	87,400	10.5
33	250°F — 3 hrs. @ 250°F	Plus 1 hr @ 325°F	76,200	86,900	14.0
34			76,000	85,900	13.0
Avg.			76,100	86,400	13.5
35		Plus 2 hrs @ 325°F	77,200	86,300	12.5
36			79,200	86,300	12.5
Avg.			78,200	86,650	12.5
37		Plus 3 hrs @ 325°F	78,600	86,200	11.5
38			80,500	86,700	11.0
Avg.			79,550	86,450	11.3
39		Plus 4 hrs @ 325°F	81,000	87,200	11.0
40			80,300	86,800	10.5
Avg.			80,650	87,000	10.8
41		Plus 5 hrs @ 325°F	76,400	86,100	10.5
42			82,300	85,400	12.0
Avg.			79,350	85,750	11.5

Sample No	Interrupted Aging Treatment		Mechanical Properties T.Y.S.	U.T.S.	% Elong.
43	250°F — 4 hrs. @ 250°F	Plus 4 hrs @ 300°F	78,155	87,375	12.0
44			76,440	87,230	13.5
45			78,995	87,515	12.5
46			78,405	87,695	13.0
Avg.			78,000	87,300	12.8
47	310°F — 4 hrs. @ 310°F	Plus 4 hrs @ 325°F	78,060	85,775	11.5
48			80,235	86,975	11.5
Avg.			79,330	86,375	11.5

MARC REPORT NO. 56-119

CONTROL SPECIMENS

Sample No	Standard Aging Treatment	Mech. Properties T.Y.S.	U.T.S.	% Elong.
1	24 hrs. @ 250°F	77,200	87,900	13.5
2	" " "	79,700	89,300	14.0
Avg.		79,450	89,250	13.8

TABLE II.

EFFECT OF VARIOUS INTERRUPTED-AGING TREATMENTS ON THE MECHANICAL PROPERTIES OF 0.064" CLAD X7178 SHEET.

Sample No.	Interrupted Aging Treatment		Mechanical Properties T.Y.S.	U.T.S.	% Elong.
3	4 HRS. @ 212°F.	Plus 2 HRS. @ 325°F.	66,185	77,020	10.5
4			68,320	77,850	12.0
Avg.			67,210	77,435	11.3
5		Plus 3 HRS. @ 325°F.	66,770	78,215	11.5
6			67,290	77,580	10.0
Avg.			67,030	77,900	10.8
7		Plus 4 HRS. @ 325°F.	70,270	78,060	11.5
8			68,500	77,100	10.5
Avg.			69,385	77,580	11.0
9		Plus 5 HRS. @ 325°F.	67,870	77,230	10.5
10			66,740	76,630	10.5
Avg.			67,305	76,930	10.5
11	4 HRS. @ 230°F.	Plus 2 HRS. @ 325°F.	69,360	77,930	12.0
12			66,445	77,545	12.0
Avg.			67,900	77,740	12.0
13		Plus 3 HRS. @ 325°F.	70,115	78,060	11.5
14			68,660	77,690	12.0
Avg.			69,390	77,850	11.8
15		Plus 4 HRS. @ 325°F.	69,120	77,840	10.5
16			68,045	77,520	11.0
Avg.			68,580	77,680	10.8
17		Plus 5 HRS. @ 325°F.	68,410	77,330	10.0
18			68,065	77,540	10.5
Avg.			68,240	77,435	10.3

Sample No.	Interrupted Aging Treatment		Mechanical Properties T.Y.S.	U.T.S.	% Elong.
19	3 HRS. @ 250°F.	Plus 2 HRS. @ 300°F.	66,965	78,920	14.5
20			65,845	77,715	15.0
Avg.			66,405	78,320	14.8
21		Plus 3 HRS. @ 300°F.	67,150	77,395	12.5
22			69,280	77,770	13.0
Avg.			68,215	77,580	12.8
23		Plus 4 HRS. @ 300°F.	66,215	79,620	13.0
24			68,455	77,920	12.0
Avg.			67,335	78,770	12.5
25		Plus 5 HRS. @ 300°F.	66,300	77,850	14.5
26			68,565	78,695	12.5
Avg.			67,430	78,275	13.5
27	3 HRS. @ 250°F.	Plus 2 HRS. @ 325°F.	66,070	77,525	12.0
28			67,040	77,230	12.5
Avg.			66,555	77,380	12.3
29		Plus 3 HRS. @ 325°F.	69,430	77,535	11.0
30			68,435	78,440	11.5
Avg.			68,930	77,990	11.3
31		Plus 4 HRS. @ 325°F.	68,820	77,480	11.0
32			69,500	77,420	10.5
Avg.			69,160	77,450	10.8
33		Plus 5 HRS. @ 325°F.	68,010	77,140	10.0
34			67,600	76,585	12.0
Avg.			67,805	76,860	11.0

Sample No.	Interrupted Aging Treatment		Mechanical Properties T.Y.S.	U.T.S.	% Elong.	
35	4 HRS. @ 250°F.	Plus 4 HRS. @ 300°F.	67,715	77,230	12.0	WADC Recom-mendation T.R. 54-119
36			67,095	77,310	12.0	
37			67,450	76,730	12.5	
38			67,490	76,995	12.5	
Avg.			67,440	77,065	12.3	
39		Plus 4 HRS. @ 325°F.	66,645	77,470	10.5	
40			69,025	76,960	11.0	
41			69,450	77,730	10.5	
42			69,655	77,610	11.5	
Avg.			68,695	77,440	10.9	

CONTROL SPECIMENS

Sample No.	Standard Aging Treatment	Mechanical Properties T.Y.S.	U.T.S.	% Elong.
1	24 HRS @ 250°F.	69,390	81,265	14.5
2	" " " "	67,040	78,010	14.0
43	" " " "	68,390	79,675	14.5
44	" " " "	67,560	79,055	14.5
Avg.		68,085	79,500	14.4

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FORM 72

TABLE III.

EFFECT OF VARIOUS INTERRUPTED-AGING TREATMENTS ON THE MECHANICAL PROPERTIES OF 0.125" X7178 EXTRUDED 1.25" x 1.25" ANGLE.

Sample No.	Interrupted-Aging Treatment	Mechanical Properties T.Y.S.	U.T.S.	% Elong.
3	Plus 2 Hrs @ 325°F.	89,210	96,590	10.5
4		86,940	96,140	12.0
Avg.		88,075	96,365	11.3
5	Plus 3 Hrs @ 325°F.	85,575	93,590	11.0
6		87,835	94,065	9.0
Avg.		86,705	93,825	10.0
7	Plus 4 Hrs @ 325°F.	87,830	95,815	9.5
8		89,655	95,925	10.0
Avg.		88,740	95,870	9.8
9	Plus 5 Hrs @ 325°F.	85,130	93,075	9.5
10		91,415	94,510	11.5
Avg.		88,270	93,790	10.5
11	Plus 2 Hrs @ 325°F	86,200	94,095	12.5
12		89,290	96,970	10.0
Avg.		87,745	95,510	11.3
13	Plus 3 Hrs @ 325°F.	86,625	93,100	11.0
14		90,320	95,715	10.0
Avg.		88,470	94,410	10.5
15	Plus 4 Hrs @ 325°F.	85,120	92,955	10.0
16		86,530	94,220	10.0
Avg.		85,825	93,590	10.0
17	Plus 5 Hrs @ 325°F.	84,225	92,875	11.5
18		85,000	94,180	10.0
Avg.		84,610	93,530	10.8

Sample No	Interrupted-Aging Treatment	Mechanical Properties T.Y.S	U.T.S.	% Elong
19	Plus 2 Hrs @ 300°F	87,760	97,175	13.5
20		87,865	98,520	12.5
Avg.		87,810	97,850	13.0
21	Plus 3 Hrs @ 300°F.	86,800	95,585	11.5
22		81,870	92,065	11.5
Avg.		84,335	93,825	11.5
23	Plus 4 Hrs @ 300°F.	88,905	96,995	12.5
24		91,360	99,085	13.0
Avg.		90,135	98,015	12.8
25	Plus 5 Hrs @ 300°F.	86,655	95,006	11.5
26		93,155	99,420	12.5
Avg.		89,905	97,210	12.0
27	Plus 2 Hrs @ 325°F	89,365	95,715	10.0
28		91,940	98,150	10.5
Avg.		90,650	96,930	10.3
29	Plus 3 Hrs @ 325°F	88,125	95,300	9.0
30		89,985	96,140	9.5
Avg.		89,055	95,720	9.3
31	Plus 4 Hrs @ 325°F	86,510	93,695	11.0
32		88,395	96,575	10.0
Avg.		87,450	95,135	10.5
33	Plus 5 Hrs @ 325°F	84,485	91,660	11.0
34		87,445	93,950	11.5
Avg.		85,965	92,805	11.3

Sample No.	Interrupted-Aging Treatment	Mechanical Properties T.Y.S.	U.T.S.	% Elong.
35	Plus 4 Hrs @ 300°F.	88,365	96,410	11.5
36		88,745	99,210	11.0
37		89,985	96,250	12.5
38		89,970	98,135	12.0
Avg.		88,015	97,500	11.8
39	Plus 4 Hrs @ 325°F.	86,035	92,675	10.5
40		89,490	95,675	10.0
Avg.		87,765	94,175	10.3

CONTROL SPECIMENS

Sample No.	Standard Aging Treatment	Mechanical Properties T.Y.S.	U.T.S.	% Elong.
1	24 Hrs @ 250°F.	90,250	99,310	12.5
2	" " "	91,625	100,930	6.5
Avg.		90,940	100,120	9.5

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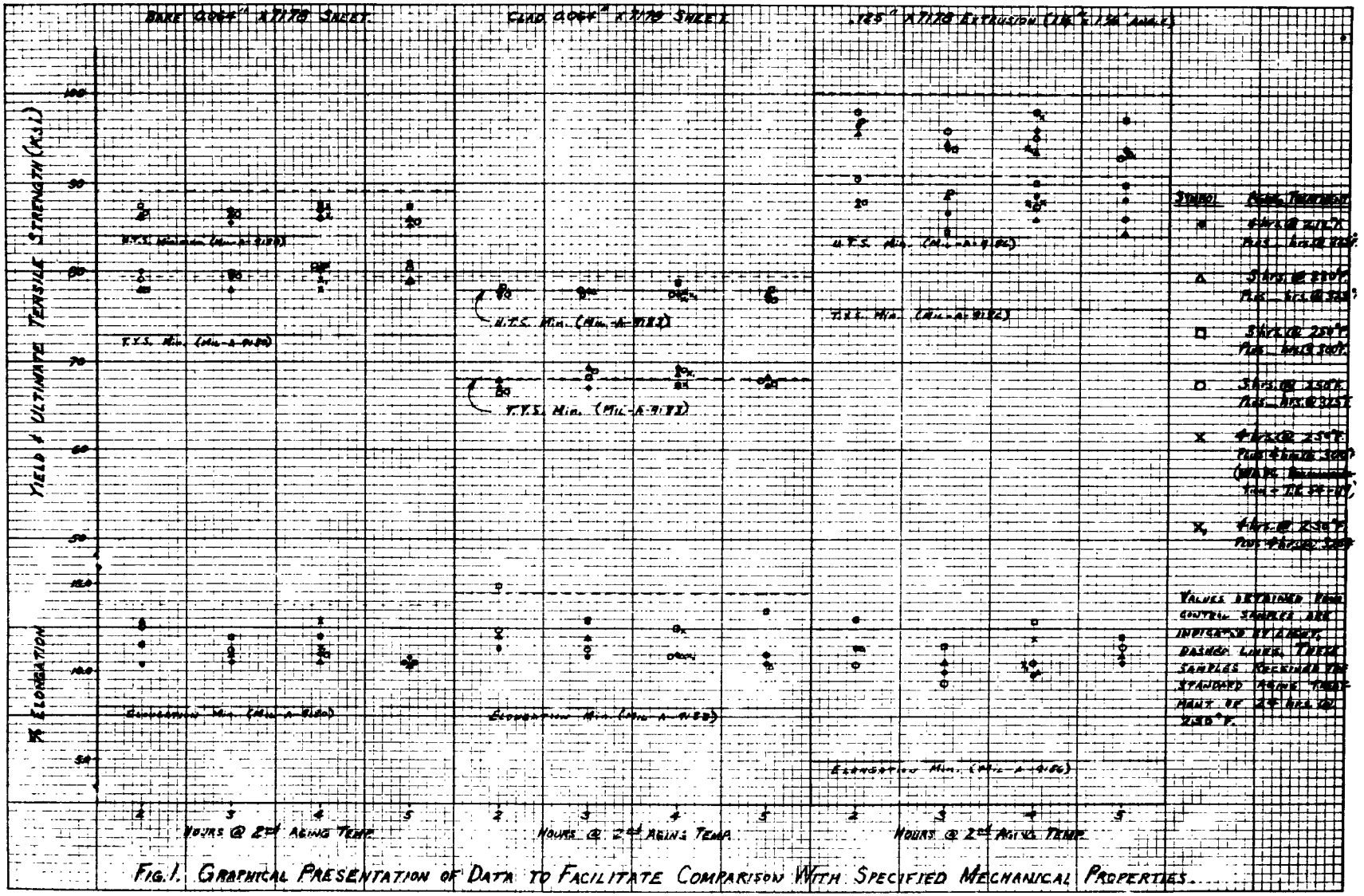

FIG. 1. GRAPHICAL PRESENTATION OF DATA TO FACILITATE COMPARISON WITH SPECIFIED MECHANICAL PROPERTIES.